US010772642B2

(12) United States Patent
Kappus et al.

(10) Patent No.: US 10,772,642 B2
(45) Date of Patent: Sep. 15, 2020

(54) **SURGICAL FORCEPS**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 396 days.

(21) Appl. No.: **15/672,383**

(22) Filed: **Aug. 9, 2017**

(65) **Prior Publication Data**

US 2018/0049752 A1 Feb. 22, 2018

Related U.S. Application Data

(60) Provisional application No. 62/376,434, filed on Aug. 18, 2016.

(51) **Int. Cl.**
A61B 17/00 (2006.01)
A61B 17/16 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC .... ***A61B 17/1611*** (2013.01); ***A61B 17/29*** (2013.01); ***A61B 17/295*** (2013.01); (Continued)

(58) **Field of Classification Search**
CPC ..... A61B 17/28; A61B 17/29; A61B 17/1606; A61B 17/07207; A61B 17/320016; (Continued)

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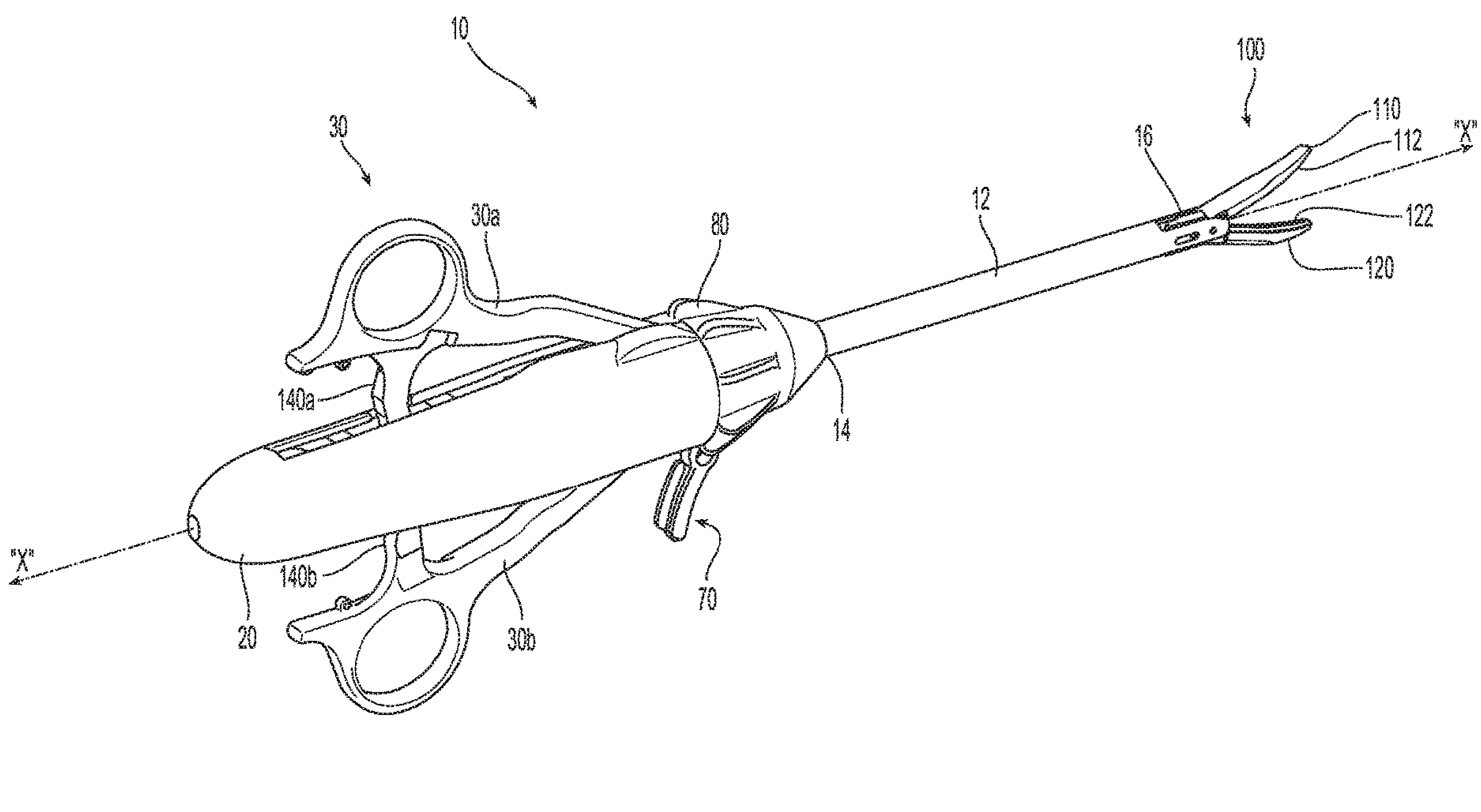
(57) **ABSTRACT**

A surgical instrument includes a housing, an elongated shaft extending distally from the housing, an end effector assembly, and a trigger assembly. The trigger assembly is disposed in mechanical cooperation with the housing and is configured to longitudinally translate a drive member. The trigger assembly includes a trigger, a gear assembly, a spool, a slider, and a flexible drive member. The trigger is disposed in mechanical cooperation with the gear assembly. The flexible drive member is configured to engage the gear assembly, the spool, and the slider. Movement of the trigger with respect to the housing results in movement of the flexible drive member with respect to the housing and longitudinal movement of the slider with respect to the housing.

19 Claims, 18 Drawing Sheets



(51) **Int. Cl.**

A61B 17/29	(2006.01)
A61B 17/32	(2006.01)
A61B 17/295	(2006.01)
A61B 18/14	(2006.01)
A61B 17/3201	(2006.01)
A61B 34/30	(2016.01)
A61B 90/00	(2016.01)

(52) **U.S. Cl.**
CPC .. ***A61B 17/320016*** (2013.01); ***A61B 18/1445*** (2013.01); *A61B 17/3201* (2013.01); *A61B 34/30* (2016.02); *A61B 90/03* (2016.02); *A61B 2017/00353* (2013.01); *A61B 2017/2913* (2013.01); *A61B 2017/2915* (2013.01); *A61B 2017/2923* (2013.01); *A61B 2018/1452* (2013.01)

(58) **Field of Classification Search**
CPC .. A61B 2017/00353; A61B 2017/2923; A61B 2017/2943
See application file for complete search history.

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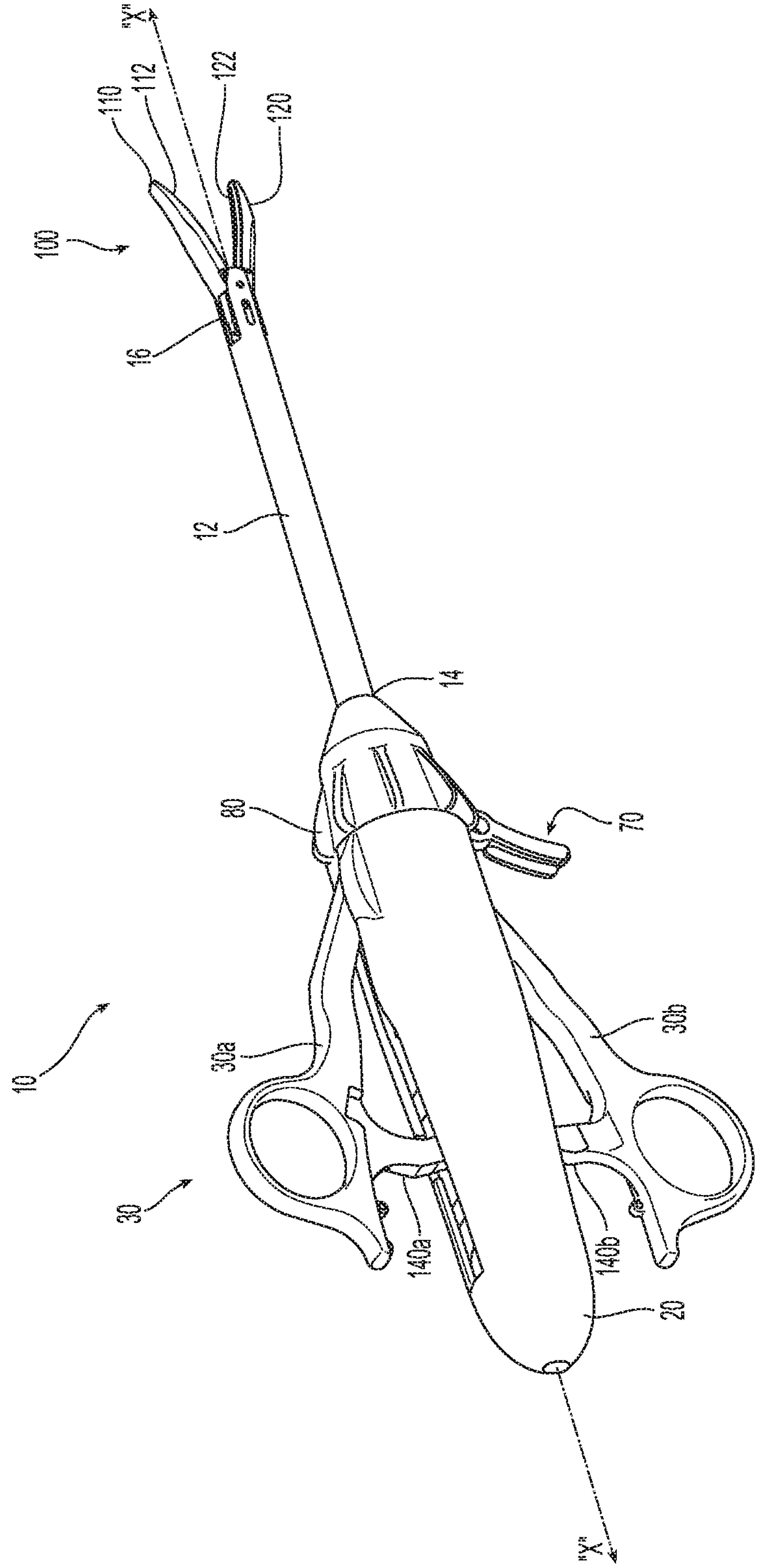

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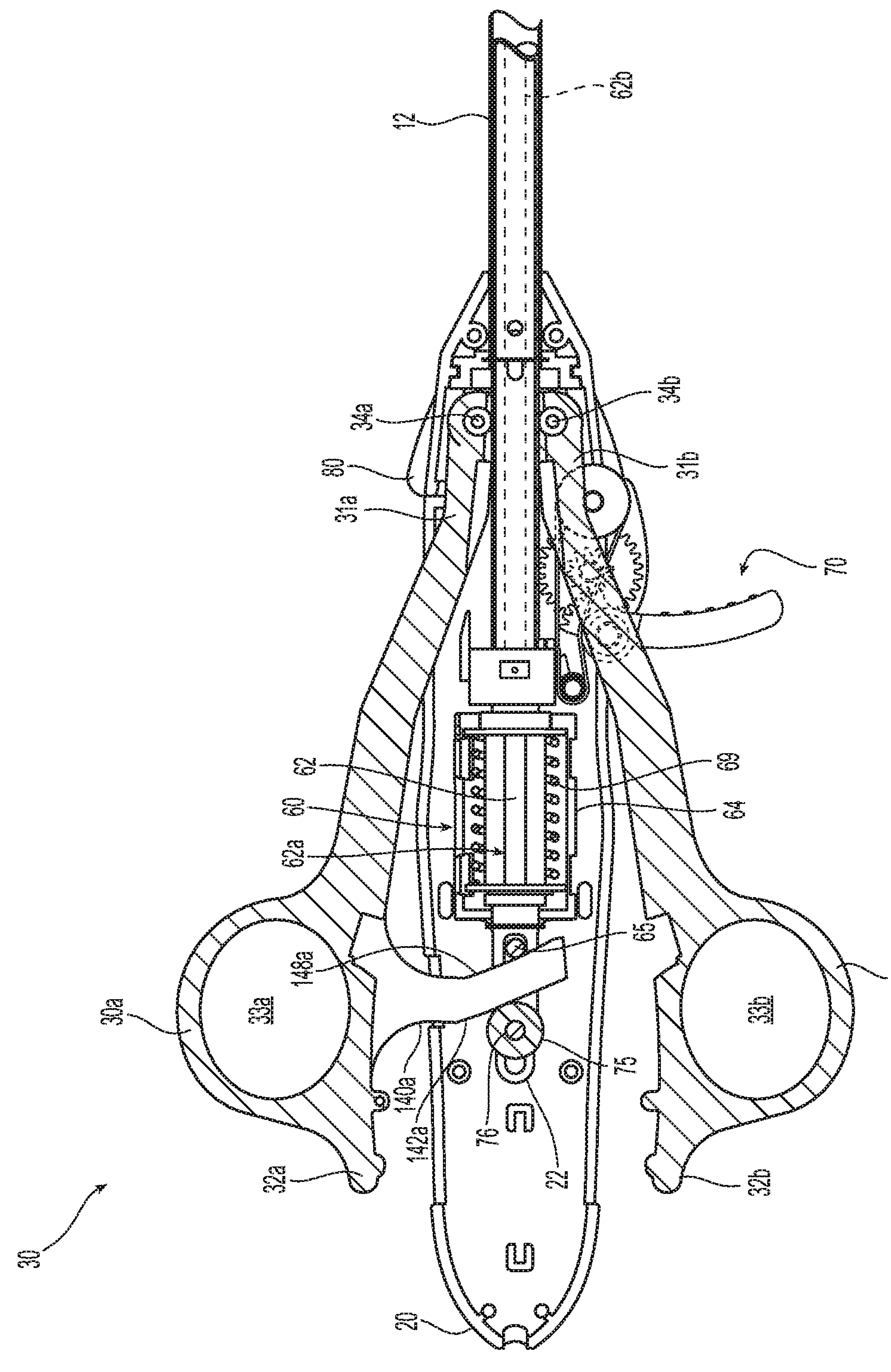
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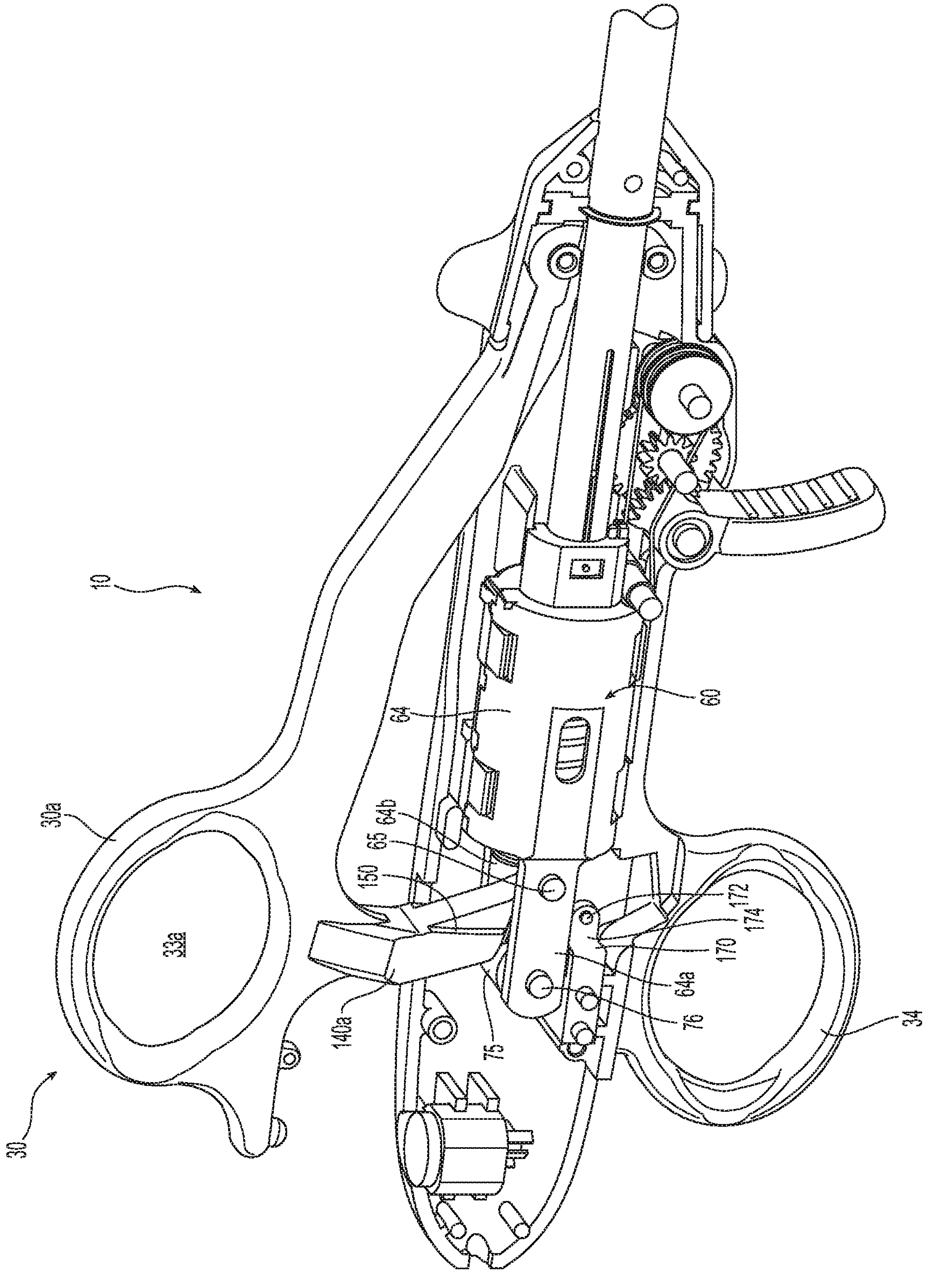
Fig. 2



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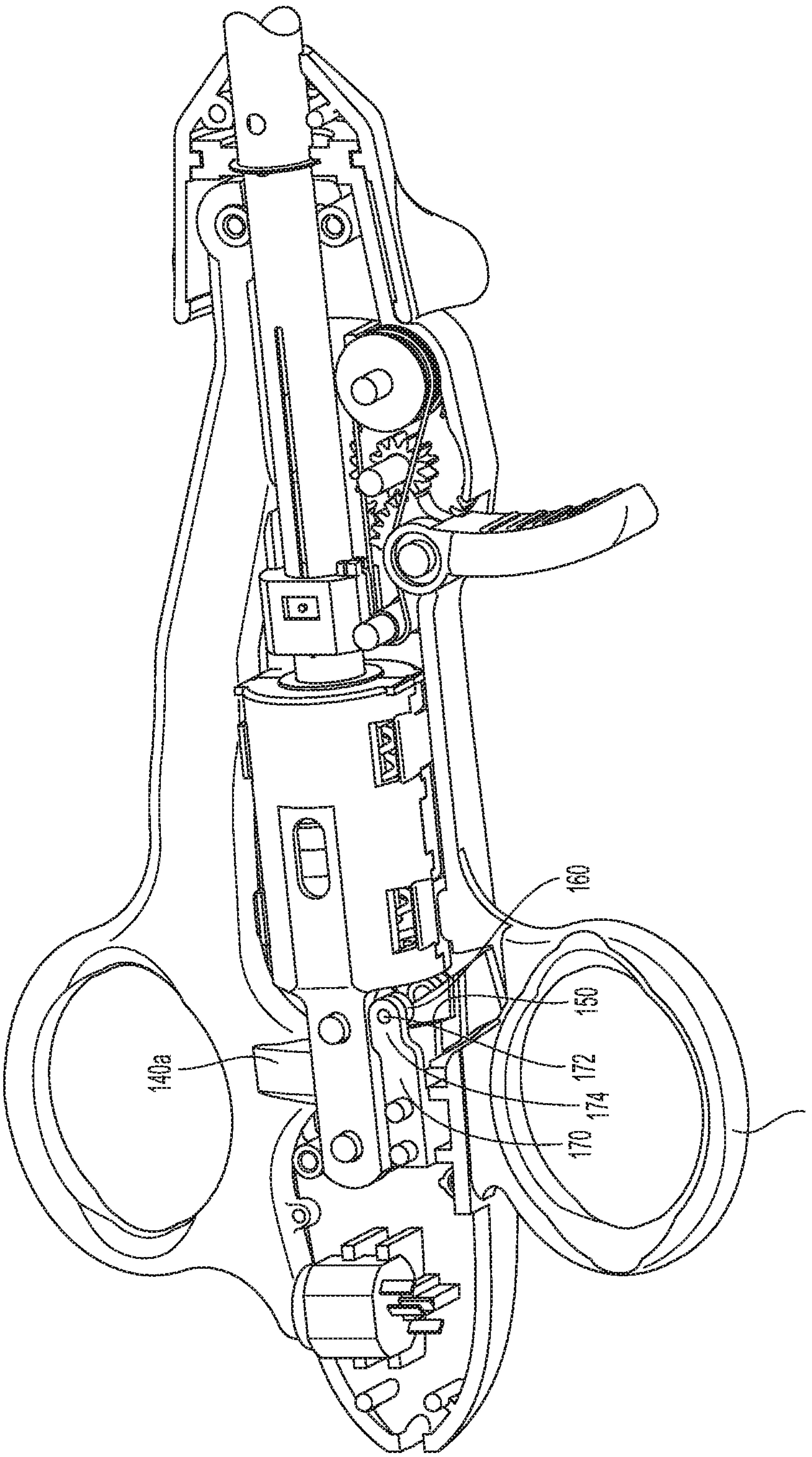

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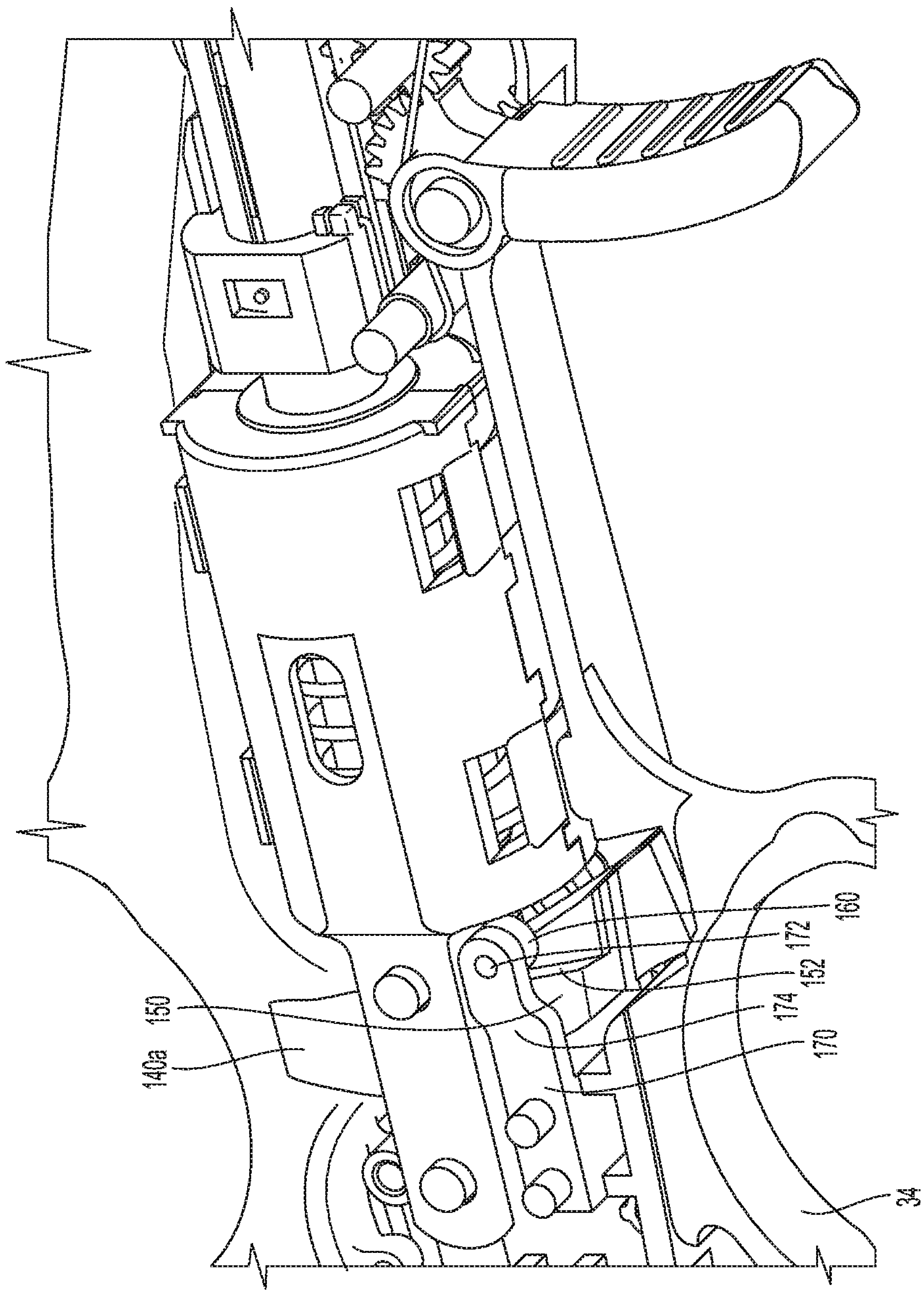

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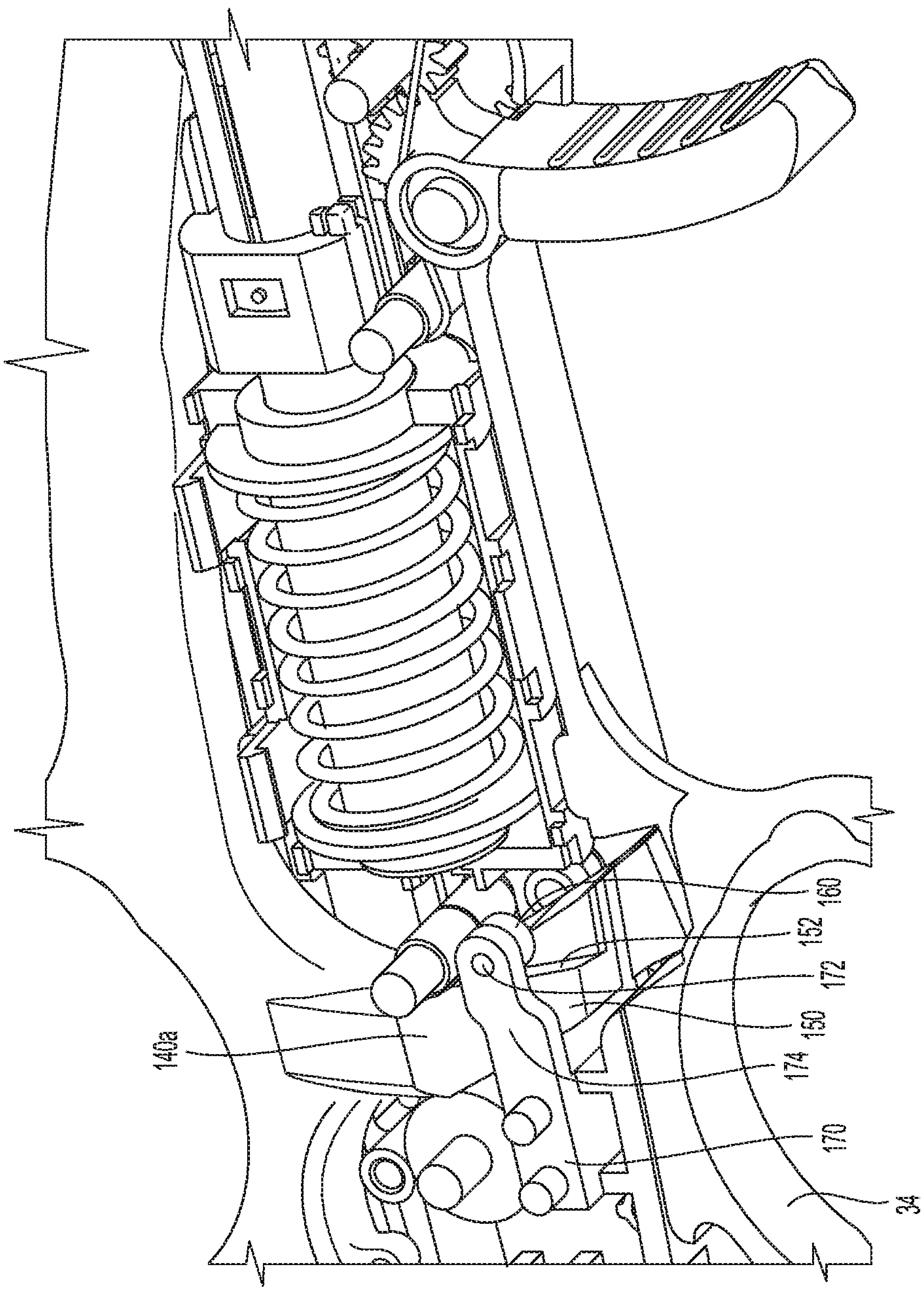

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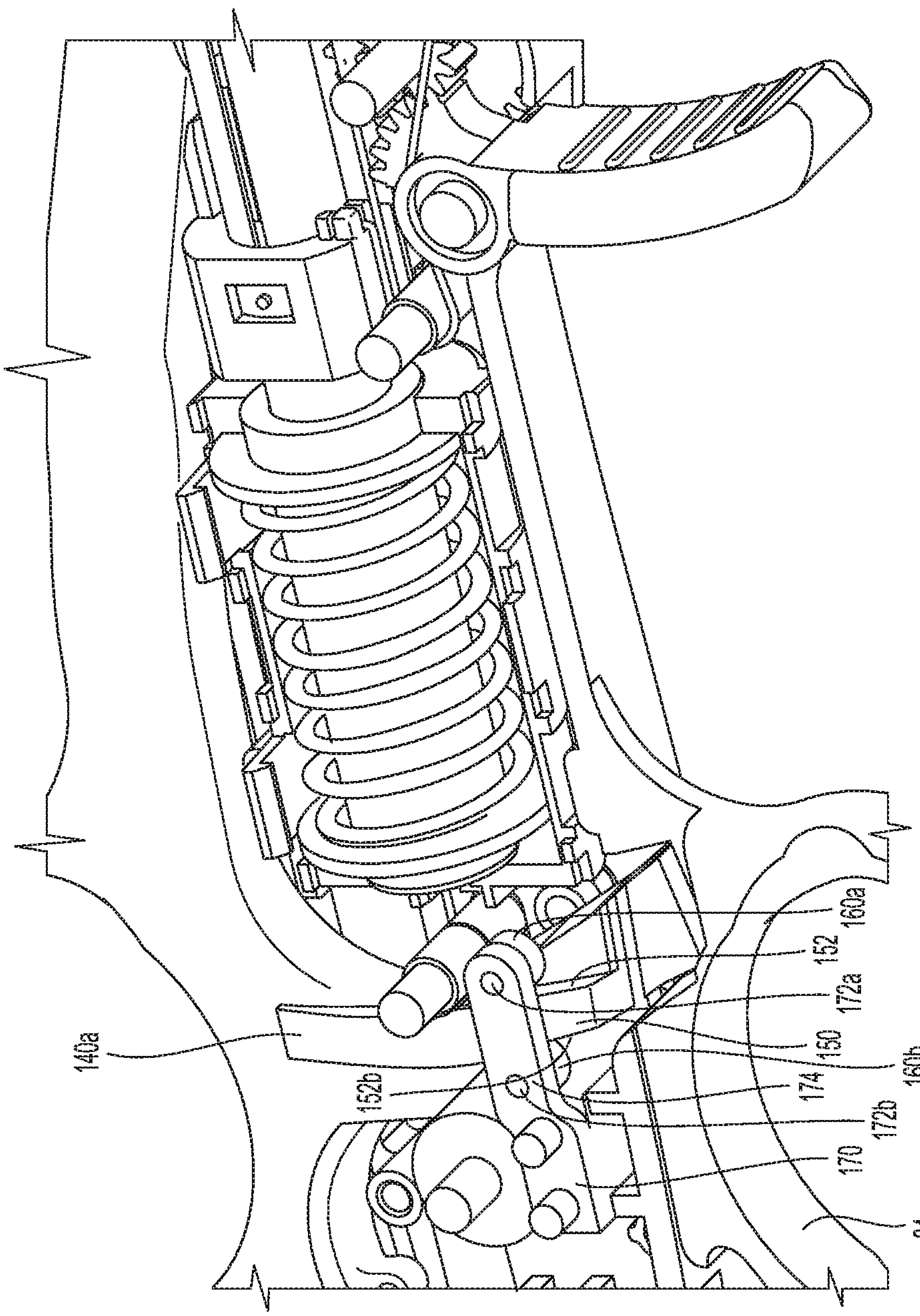

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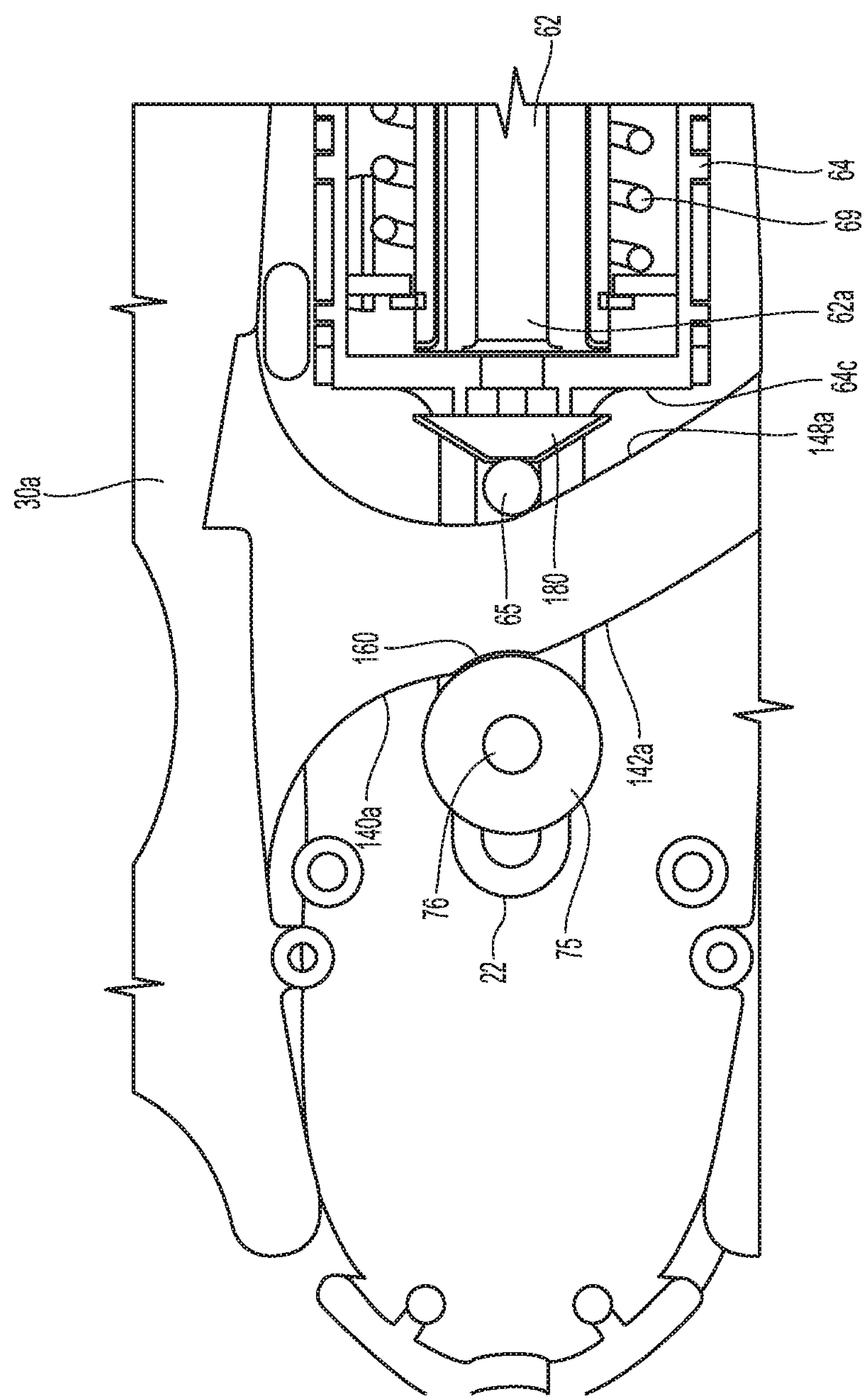

Fig. 7

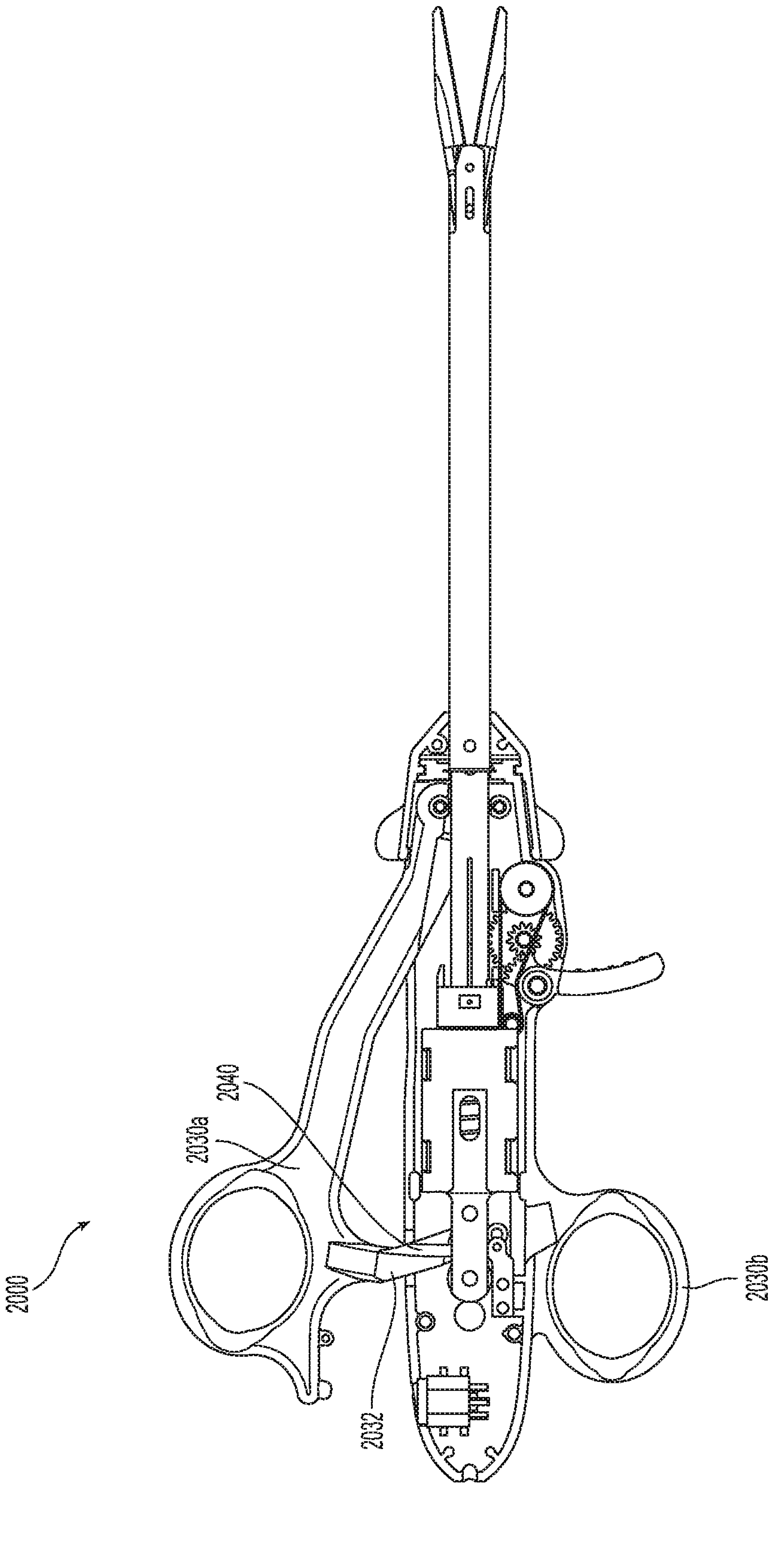

Fig. 8

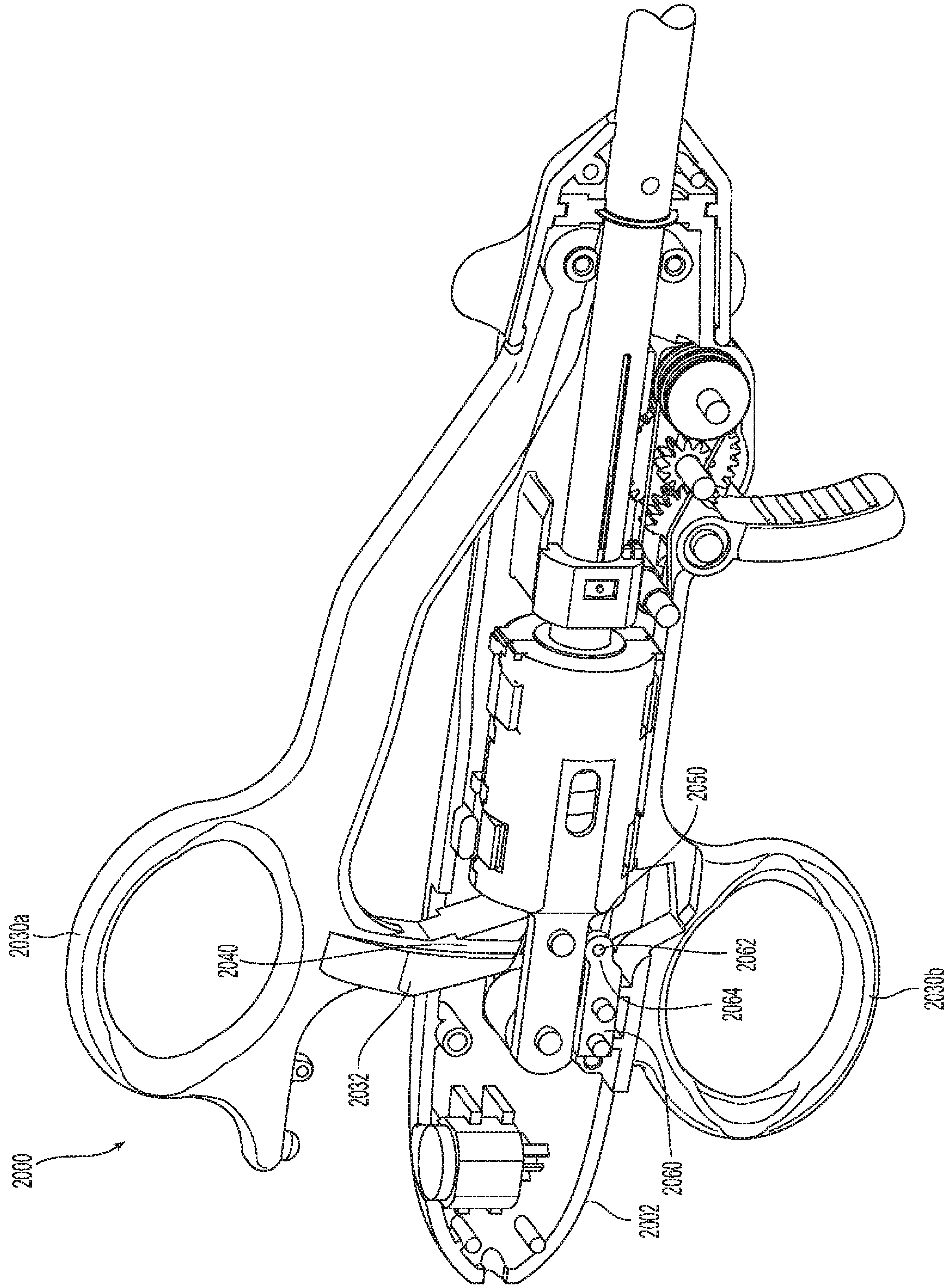

Fig. 9

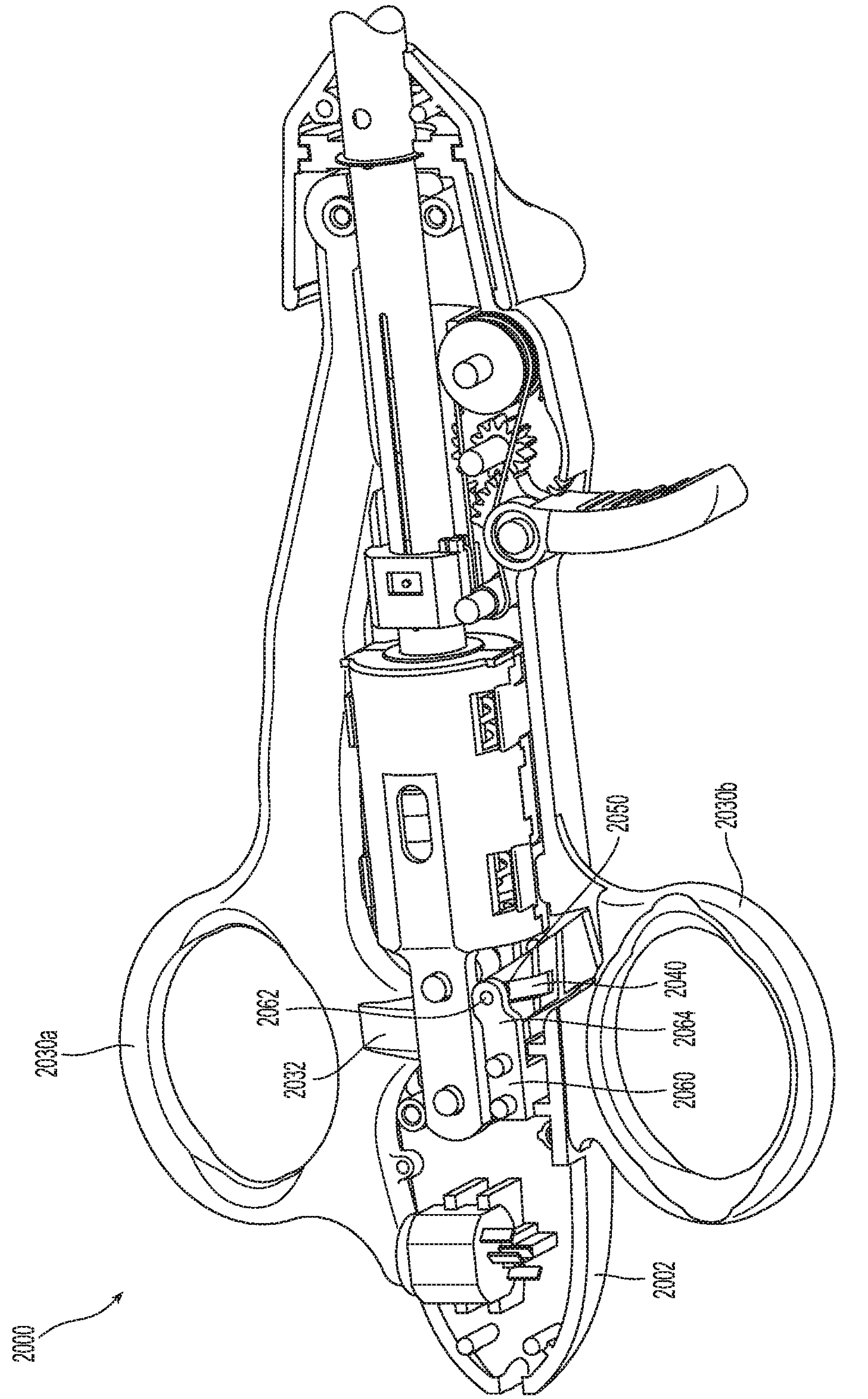

Fig. 10

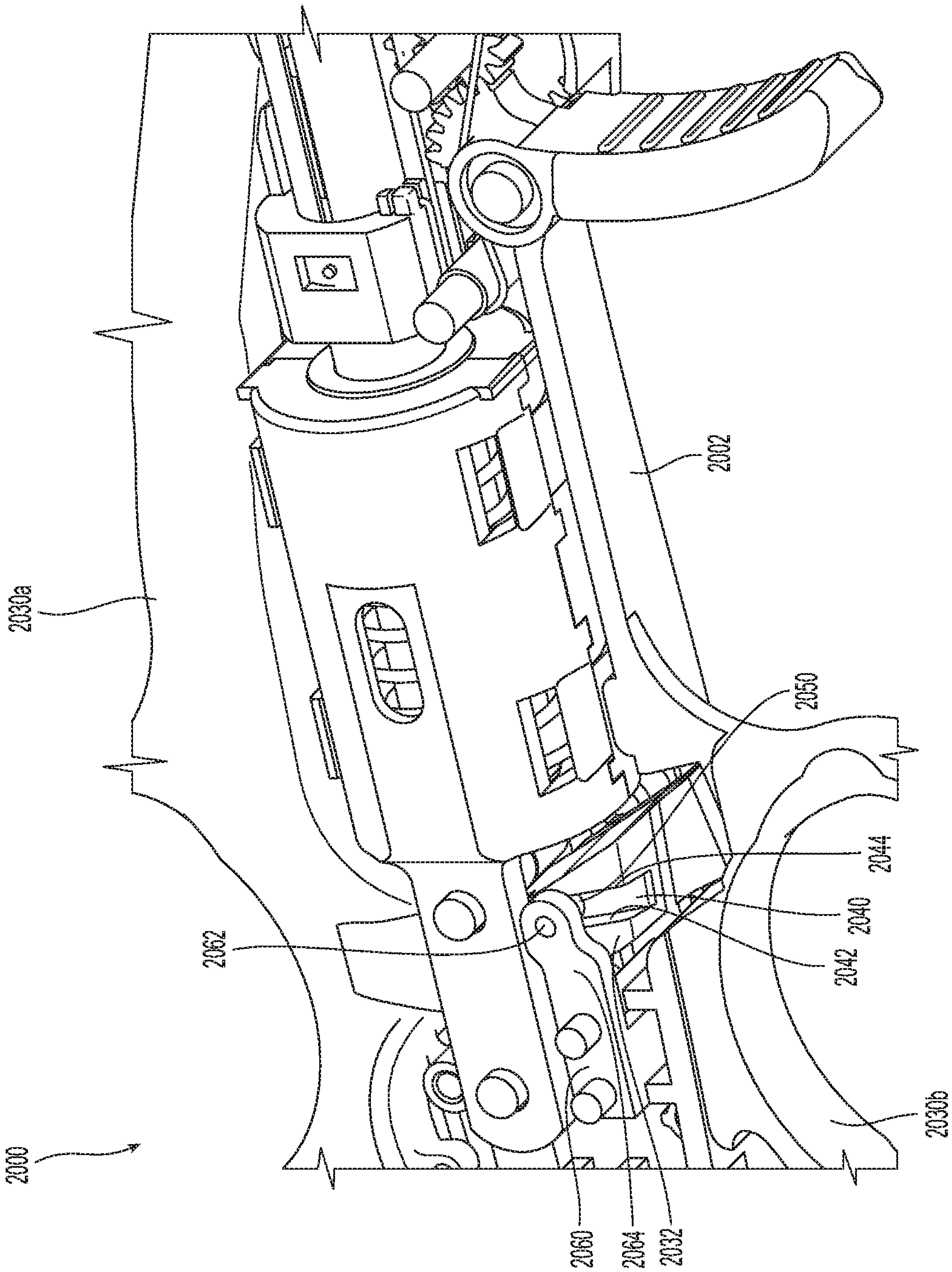
2000
2030a
2002
2050
2044
2040
2042
2062
2060
2064
2032
2030b

Fig. 11

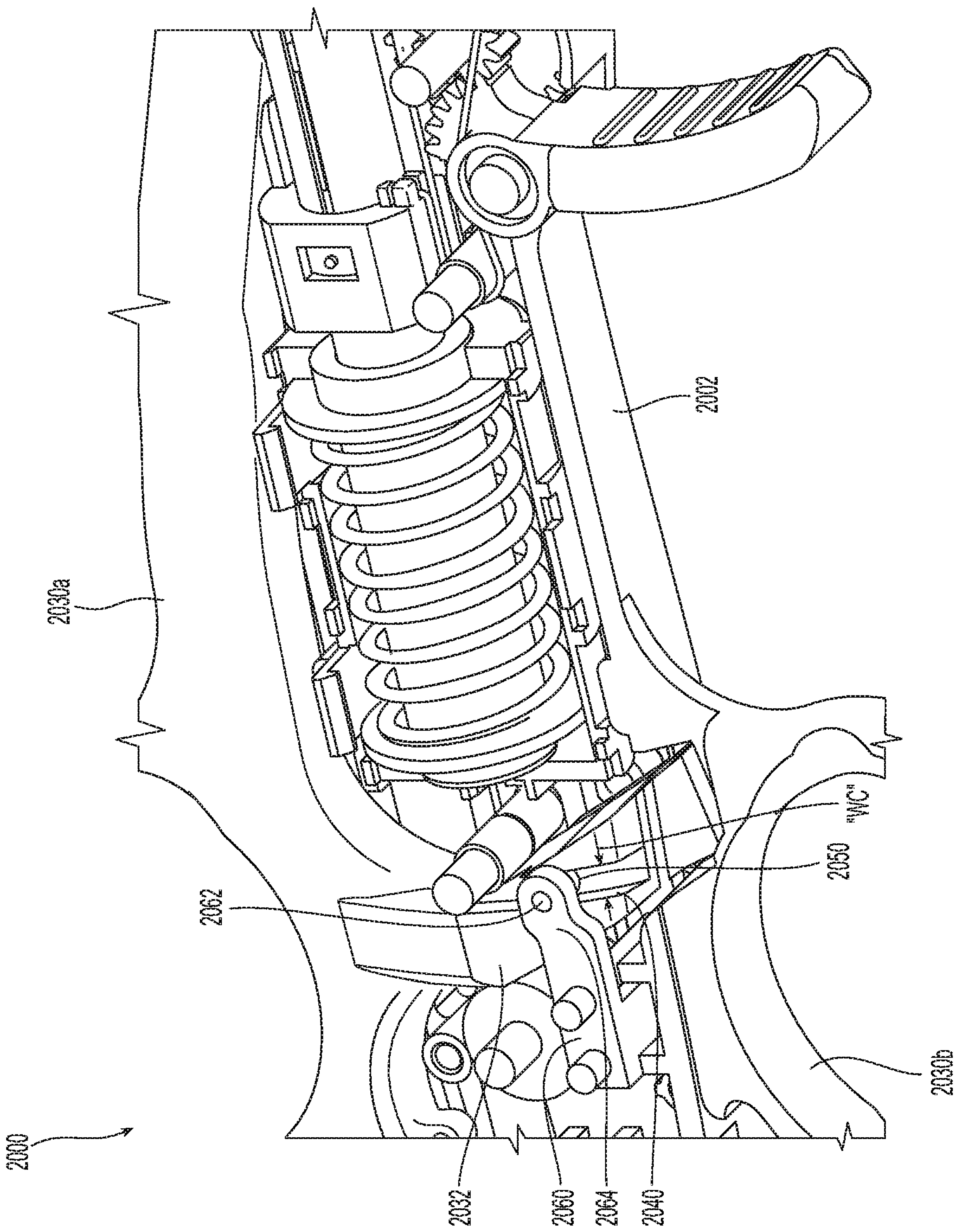

Fig. 12

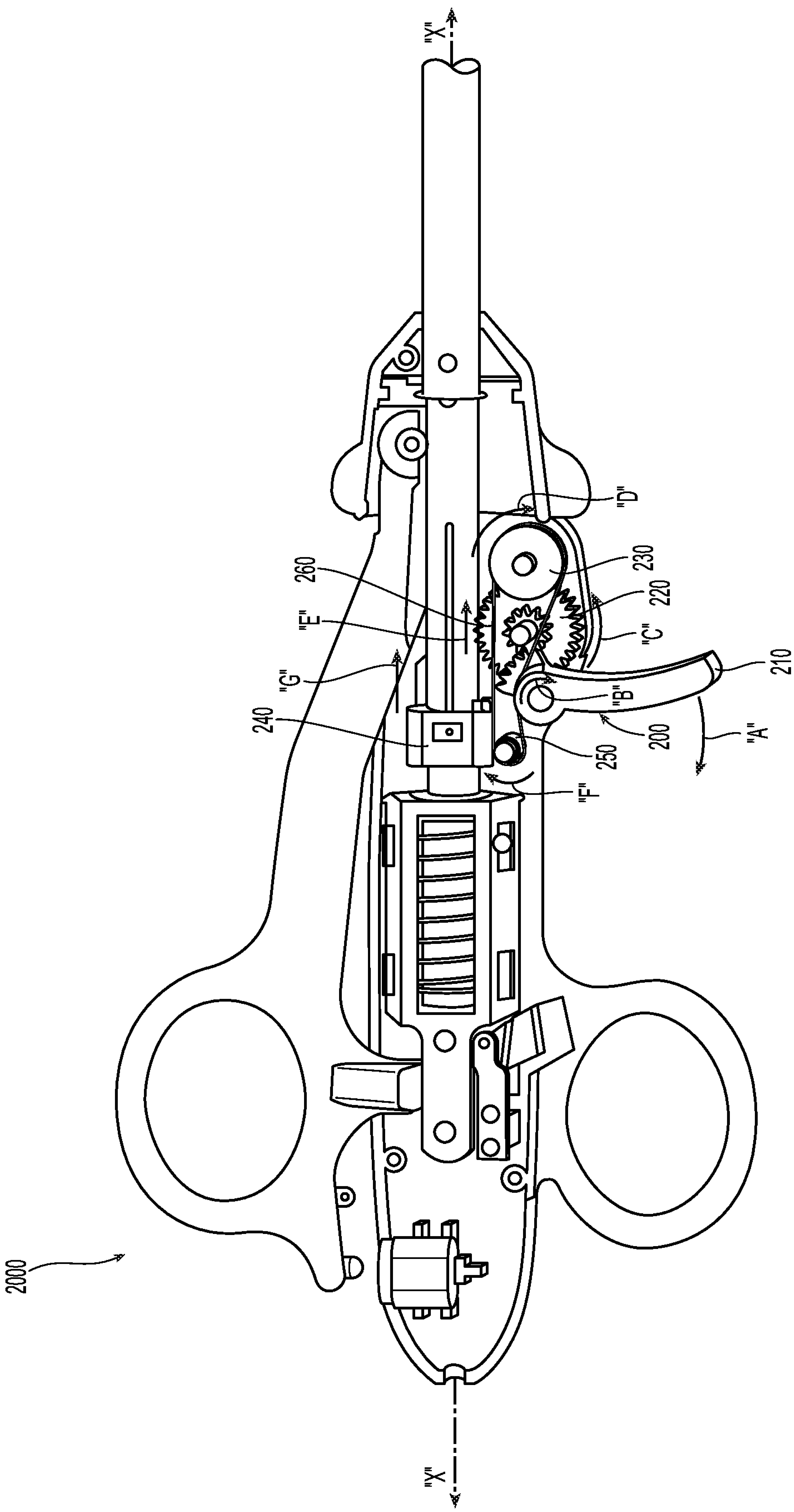

Fig. 13

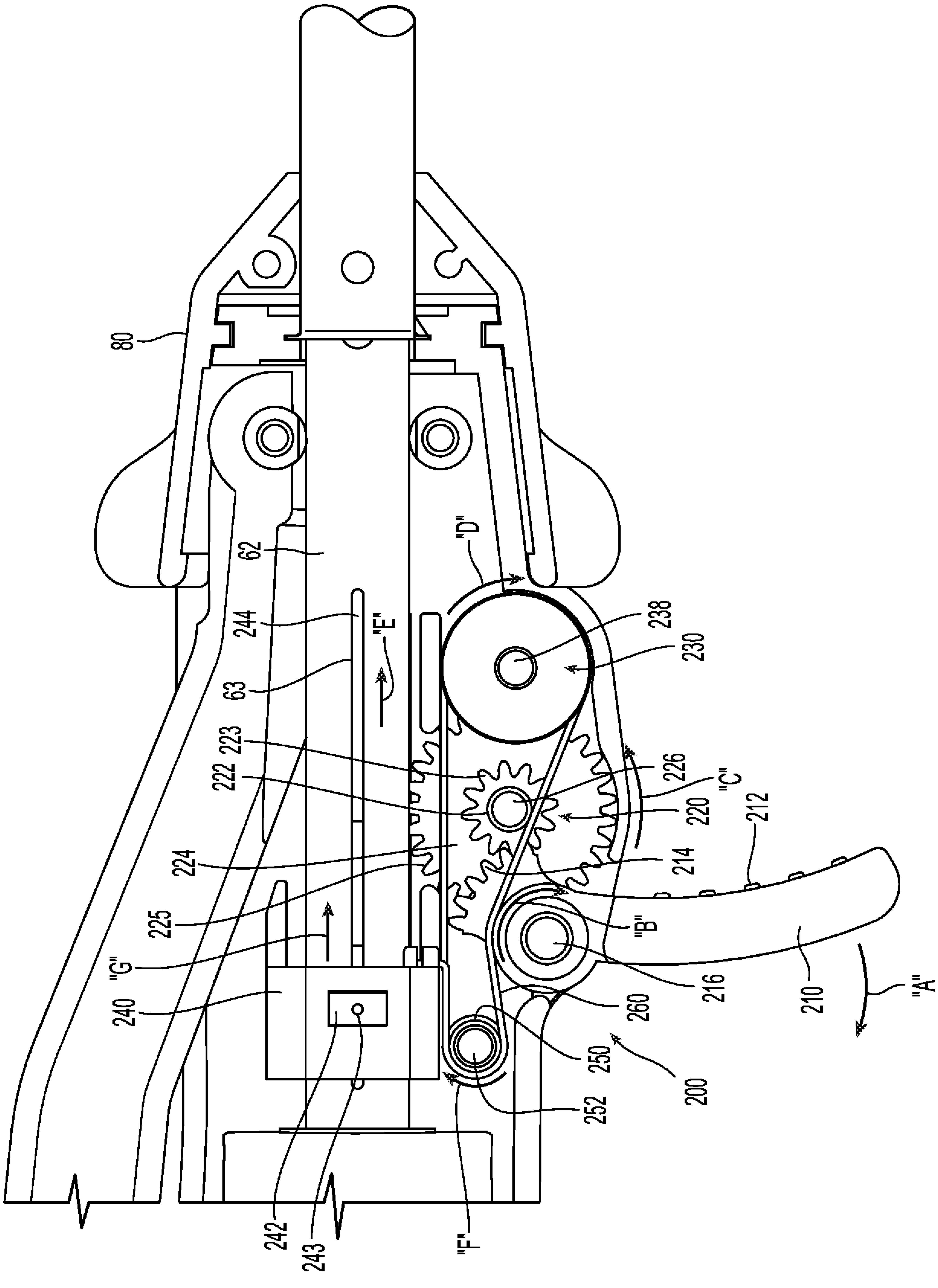
80
62
"D"
238
230
244
"E"
63
223
226
222
"C"
220
212
224
214
225
"B"
"G"
216
210
"A"
240
260
250
200
252
242
243
"F"

Fig. 14

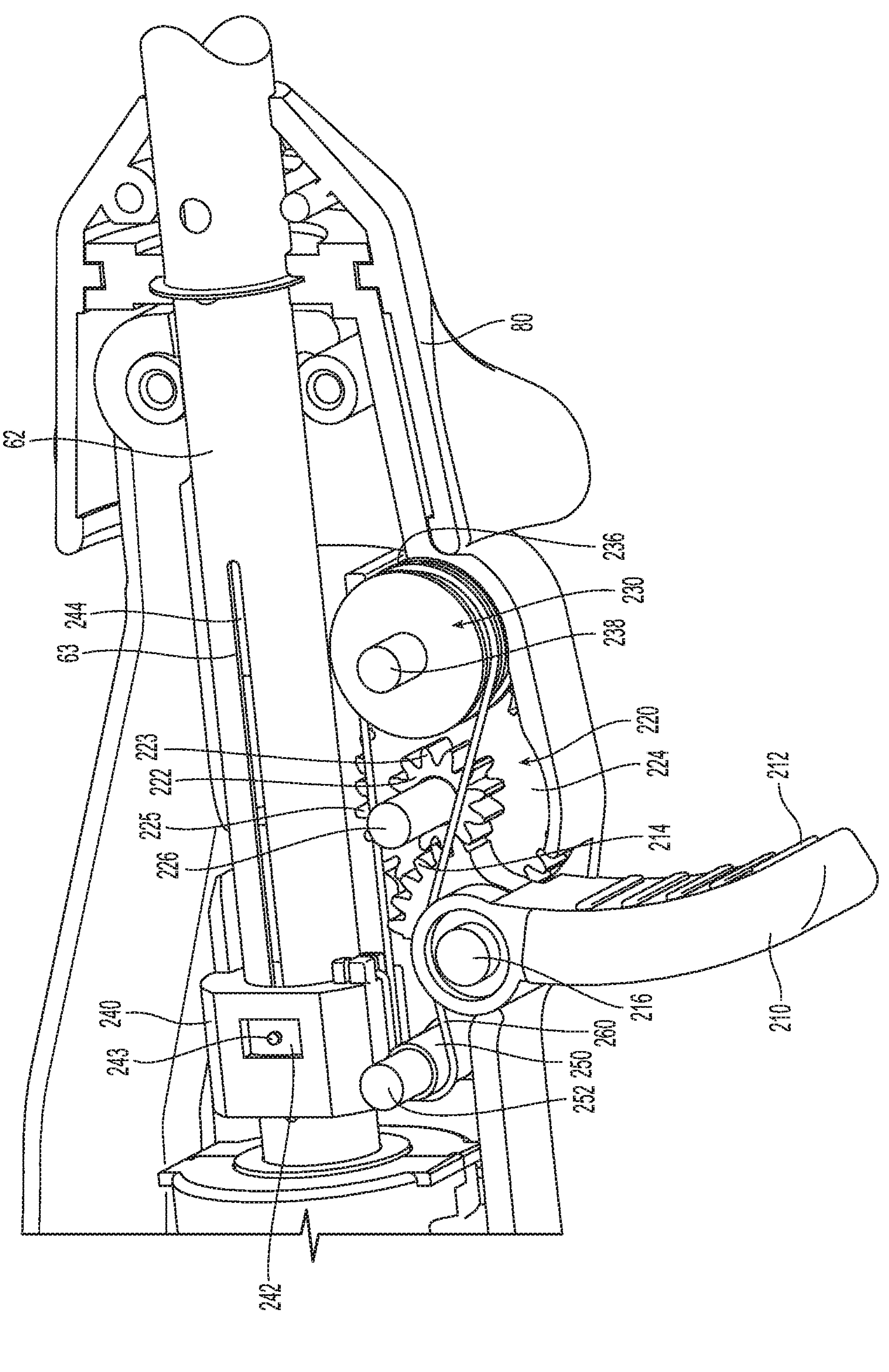
80
62
236
230
244
63
238
223
222
220
224
225
226
214
212
240
243
216
260
250
252
210
242

Fig. 15

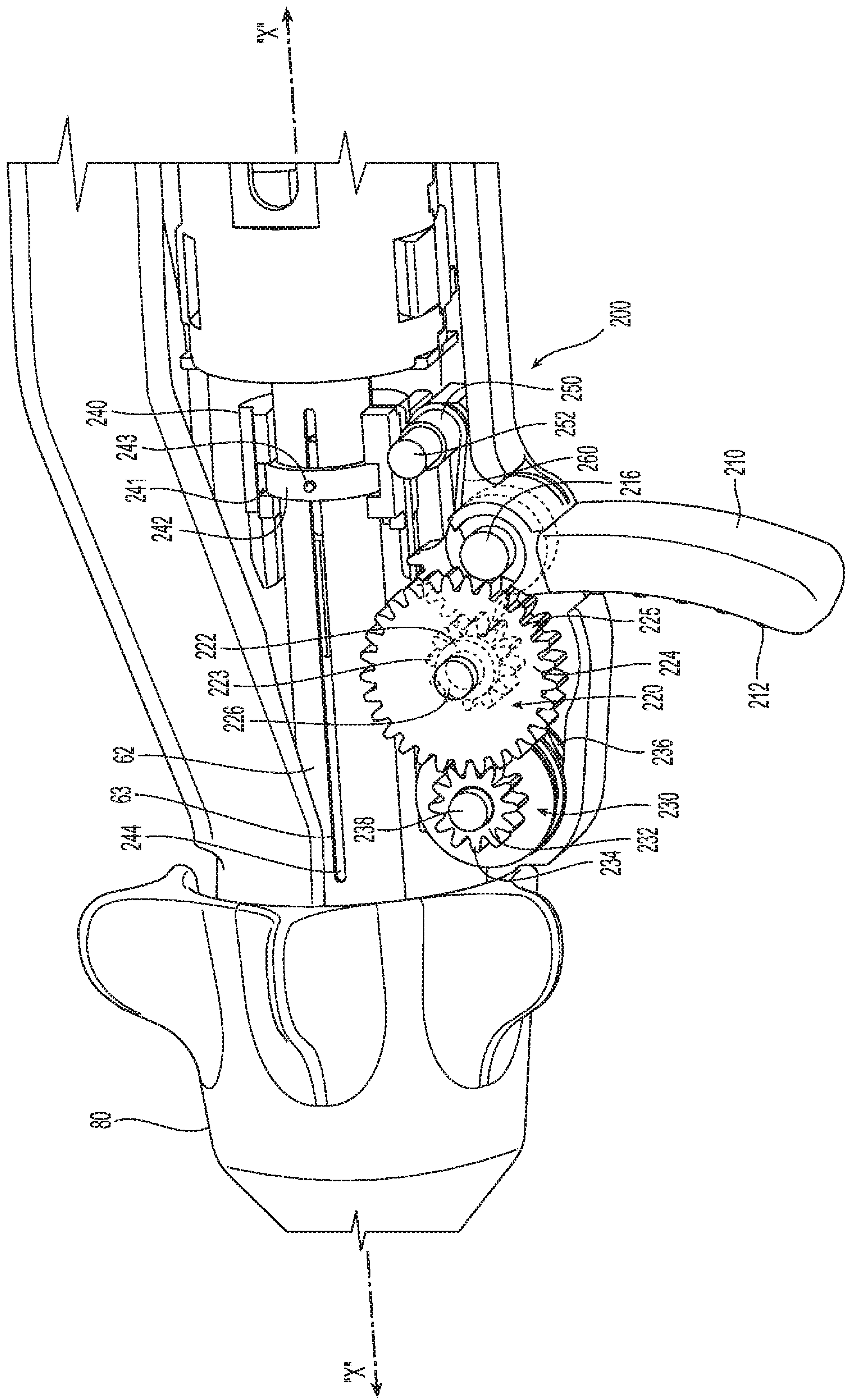
"X"
200
250
252
260
216
210
240
243
241
242
222
223
226
62
63
244
238
225
224
220
236
230
232
234
212
80
"X"

Fig. 16

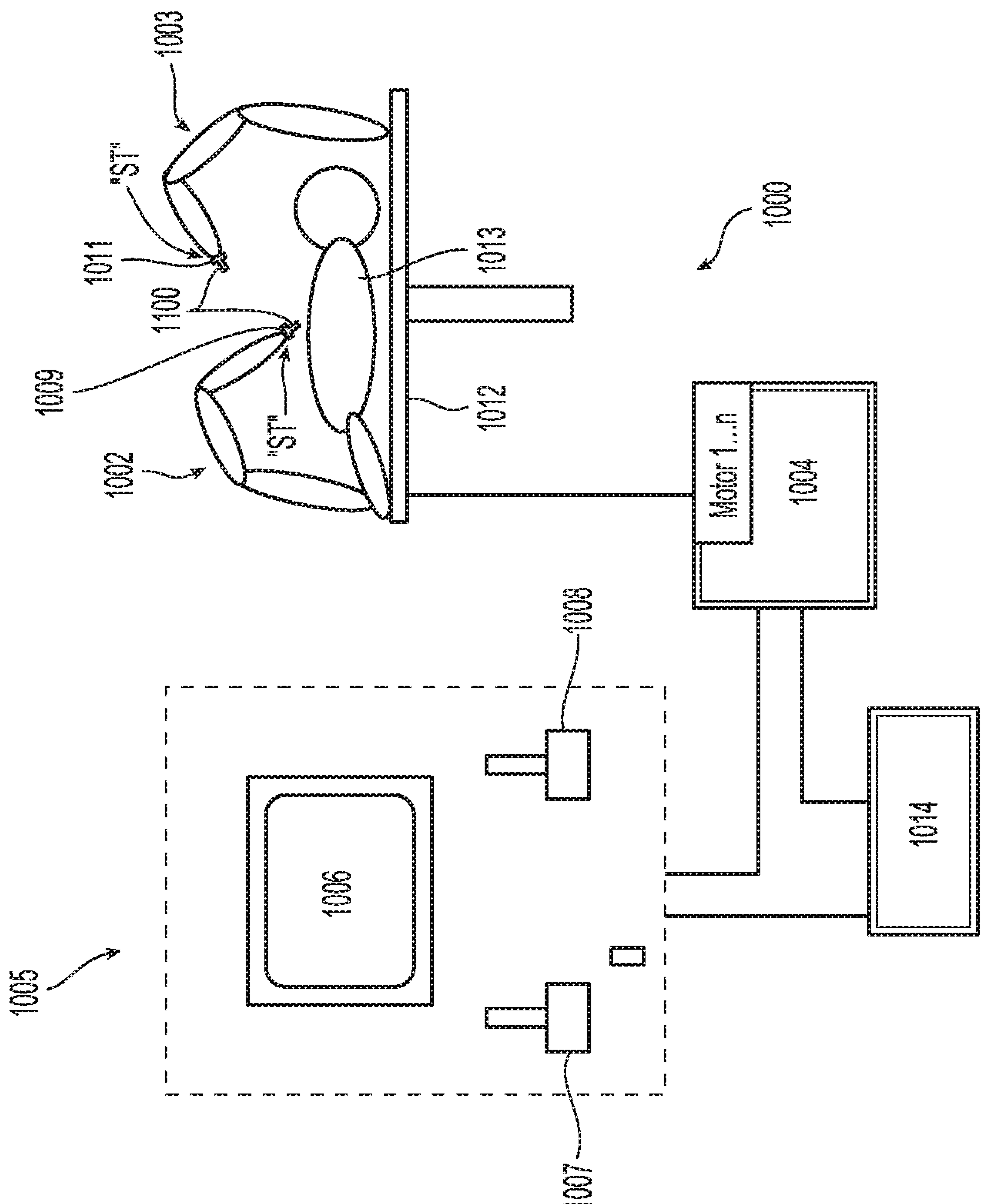
1003
"ST"
1011
1100
1009
1002
"ST"
1013
1012
1000
Motor 1...n
1004
1008
1006
1005
1007
1014

Fig. 17

SURGICAL FORCEPS

CROSS REFERENCE TO RELATED APPLICATION

The present application claims the benefit of and priority to U.S. Provisional Application Ser. No. 62/376,434, filed on Aug. 18, 2016 the entire contents of which are incorporated herein by reference.

BACKGROUND

Technical Field

The present disclosure relates to surgical forceps and, more particularly, to an endoscopic surgical forceps configured for treating and/or cutting tissue.

Background of Related Art

A surgical forceps is a pliers-like device which relies on mechanical action between its jaw members to grasp, clamp, and constrict tissue. Typically, at least one handle or lever is used to open and close the jaw members, and to provide compression force on tissue between the jaw members, to lock the jaw members in a closed position, and/or to apply energy to the jaw members to seal the tissue disposed therebetween.

Generally, such handles and levers used on surgical instruments are one of two types. One type is a simple pivoted handle that provides a near constant mechanical advantage throughout its stroke, and which is useful in many surgical situations. The second type of handle includes an additional link to provide a geometrically increasing mechanical advantage toward the end of its stroke to help provide the force necessary to compress tissue.

Both of these types of handles fix the mechanical advantage of the drive system such that the drive system cannot be optimized independently over the entire lever stroke. Often times, it may be desirable for a system to include fine dissection capability (a relatively large amount of handle travel for a relatively small amount of jaw member movement) when the jaw members are in an initial, or open position, and to include a high mechanical advantage while applying compression force to tissue disposed between the jaw members when the jaw members are in or near their approximated position (to help reduce surgeon fatigue, for instance). However, current handles are generally unable to achieve both of these desires in a single system.

SUMMARY

The present disclosure relates to a surgical instrument including a housing, an elongated shaft extending distally from the housing and defining a longitudinal axis, an end effector assembly, and a trigger assembly. The end effector assembly is disposed adjacent a distal end of the elongated shaft, and includes a first jaw member and a second jaw member. One or both of the jaw members is movable with respect to the other jaw member from a spaced-apart position to a position closer to the other jaw member for grasping tissue. The trigger assembly is disposed in mechanical cooperation with the housing and is configured to longitudinally translate a drive member. The trigger assembly includes a trigger, a gear assembly, a spool, a slider, and a flexible drive member. The trigger is disposed in mechanical cooperation with the gear assembly. The flexible drive member is configured to engage the gear assembly, the spool, and the slider. Movement of the trigger with respect to the housing results in movement of the flexible drive member with respect to the housing and longitudinal movement of the slider with respect to the housing.

In aspects of the present disclosure, the surgical instrument further includes a drive assembly disposed at least partially within the housing. The drive assembly includes a drive bar extending at least partially through the elongated shaft such that longitudinal translation of the drive bar causes the jaw members to move between the spaced-apart position and the closer position for grasping tissue.

In other aspects, the drive bar is rotatable about the longitudinal axis with respect to the housing. In yet other aspects, the drive bar is rotatable about the longitudinal axis with respect to the slider.

In still other aspects, the trigger assembly further includes a ring. The ring is rotationally supported by the slider. In aspects of the present disclosure, the ring is rotationally fixed with respect to the drive bar. In other aspects, the ring is longitudinally translatable with respect to the drive bar.

In yet other aspects, the drive member is longitudinally translatable with respect to the drive bar. In still other aspects, the drive bar is rotatable with respect to the drive member.

In aspects of the present disclosure, the gear assembly includes a first gear and a second gear. The first gear is configured to engage the trigger, and the second gear is configured to engage the spool.

The present disclosure also relates to a trigger assembly for use with a surgical instrument. The trigger assembly includes a trigger, a gear assembly disposed in mechanical cooperation with the trigger, a spool, a slider, and a flexible drive member. The flexible drive member is configured to engage the gear assembly, the spool, and the slider. Actuation of the trigger results in movement of the flexible drive member with respect to the spool and longitudinal movement of the slider with respect to the spool.

In aspects of the present disclosure, the trigger assembly includes a ring rotationally supported by the slider. In other aspects, the ring is longitudinally translatable with respect to the spool.

In still other aspects, the gear assembly includes a first gear and a second gear. The first gear is configured to engage the trigger, and the second gear is configured to engage the spool. In yet other aspects, the first gear and the second gear are rotationally fixed with respect to each other.

In aspects of the present disclosure, the flexible drive member is in contact with the spool and the slider.

In other aspects, the spool includes a spool gear having a plurality of teeth configured to engage a portion of the gear assembly.

BRIEF DESCRIPTION OF THE DRAWINGS

Various aspects of the present disclosure are described herein with reference to the drawings wherein like reference numerals identify similar or identical elements:

FIG. **1** is a perspective view of a surgical forceps provided in accordance with the present disclosure;

FIG. **2** is a sectional view of a handle assembly of the surgical forceps of FIG. **1** where a first cam of a first handle is shown, and where a second cam of a second handle is omitted;

FIGS. **3-6** are perspective views of internal components of the handle assembly of FIGS. **1** and **2**;

FIG. **6**A is a perspective view of internal components of a handle assembly according to an embodiment of the present disclosure;

FIG. **7** is a sectional view of internal components of the handle assembly of FIGS. **1-6**;

FIG. **8** is a sectional view of another embodiment of a surgical forceps provided in accordance with the present disclosure;

FIGS. **9-12** are perspective views of internal components of a handle assembly of the surgical forceps of FIG. **8**;

FIG. **13** is a sectional view of a handle assembly of another embodiment of a surgical forceps provided in accordance with the present disclosure;

FIG. **14** is a sectional view of a trigger assembly of the surgical forceps of FIG. **13**;

FIGS. **15** and **16** are perspective views of the trigger assembly of the surgical forceps of FIGS. **13-14**; and

FIG. **17** is a schematic illustration of a surgical system in accordance with the present disclosure.

DETAILED DESCRIPTION

Embodiments of the presently disclosed surgical forceps are described in detail with reference to the drawings, in which like reference numerals designate identical or corresponding elements in each of the several views. As used herein the term "distal" refers to that portion of the surgical forceps that is farther from the user, while the term "proximal" refers to that portion of the surgical forceps that is closer to the user.

With initial reference to FIG. **1**, an embodiment of a surgical forceps in accordance with the present disclosure is shown generally identified by reference character **10**. Although surgical forceps **10** is shown configured for use in connection with endoscopic surgical procedures, the present disclosure is equally applicable for surgical instruments used in open surgical procedures and in connection with any suitable surgical instrument. For the purposes herein, forceps **10** is generally described.

Forceps **10** is adapted for use in various surgical procedures and generally includes a housing **20**, a handle assembly **30**, a trigger assembly **70**, a rotating assembly **80**, and an end effector assembly **100**. Jaw members **110** and **120** of end effector assembly **100** mutually cooperate to grasp, treat, seal and/or cut tissue. Forceps **10** further includes a shaft **12** having a distal end **16** that mechanically engages end effector assembly **100**, and a proximal end **14** that mechanically engages housing **20**. Forceps **10** may be configured to connect to a source of energy, e.g., a generator (not shown), forceps **10** may be configured as a battery powered instrument, or forceps **10** may be manually powered (e.g., when providing electrosurgical energy is not desired).

As shown in FIGS. **1** and **2**, for example, handle assembly **30** includes a first movable handle **30***a* and a second movable **30***b* disposed on opposite sides of housing **20**. Handles **30***a* and **30***b* are movable relative to one another to actuate end effector assembly **100**, as will be described in greater detail below. Further, while two movable handles **30***a* and **30***b* are shown and described herein, the present disclosure also includes handle assembly **30** including a single movable handle, as shown in FIGS. **3-16**, for example. Here, in addition to the single movable handle, a finger loop **34** is included on the opposite side of housing **20** as the single movable handle. Additionally, handle **30***b* may include the same, mirror-image, or corresponding features as handle **30***a*.

Rotating assembly **80** is mechanically coupled to housing **20** and is rotatable in either direction, to rotate shaft **12** and, thus, end effector assembly **100** about a longitudinal axis "X" defined by shaft **12**. Such a configuration allows end effector assembly **100** to be rotated in either direction with respect to housing **20**.

Handle(s) **30***a* and/or **30***b* of handle assembly **30** ultimately connect to a drive assembly **60** disposed within housing **20** and that extends through shaft **12** which, together, cooperate to impart movement of jaw members **110** and **120** from an open position wherein jaw members **110** and **120** are disposed in spaced relation relative to one another, to a closed or approximated position wherein jaw members **110** and **120** cooperate to grasp tissue therebetween.

Handles **30***a* and **30***b* of handle assembly **30** each include a finger loop or an aperture **33***a* and **33***b*, respectively, defined therein which enables a user to grasp and move handles **30***a* and **30***b* relative to one another and relative to housing **20** between a spaced-apart position and an approximated position. In the embodiment where handle assembly **30** includes two handles **30***a* and **30***b*, each handle **30***a* and **30***b* is pivotably coupled to housing **20** at its respective distal end **31***a*, **31***b* via pivot pins **34***a*, **34***b*, respectively, and extends proximally to proximal ends **32***a*, **32***b*, respectively, thereof. As mentioned above, handles **30***a*, **30***b* are coupled to drive assembly **60** such that pivoting of handles **30***a*, **30***b* about pivot pins **34***a*, **34***b*, respectively, and relative to one another effects pivoting of jaw members **110**, **120** between the open and closed positions, as discussed in further detail below. In the embodiment where handle assembly **30** includes a single movable handle **30***a* and a finger loop **34**, handle **30***a* is pivotably coupled to housing at its distal end **31***a* via pivot pin **34***b*. Here, movement of handle **30***a* with respect to housing **20** effects pivoting of jaw members **110**, **120** between the open and closed positions.

With particular reference to FIG. **2**, drive assembly **60** includes a drive bar **62** defining a proximal end **62***a* disposed within housing **20** and a distal end **62***b* that extends through shaft **12**, ultimately coupling to jaw members **110**, **120**. A mandrel **64** disposed within housing **20** is engaged with the proximal end **62***a* of drive bar **62**. Mandrel **64** is slidably engaged with at least one track **22** (see FIG. **2**) defined within housing **20** to guide longitudinal translation of mandrel **64** and, thus, drive bar **62**, relative to housing **20**. Other suitable guide/alignment mechanisms are also contemplated. A spring **69** is positioned within mandrel **64** and is configured to prevent over compression of tissue when jaw members **110**, **120** are in the closed or approximated position.

A follower **75** is rotatably supported by an axle **76**, which extends through a bore of follower **75**. Axle **76** is supported (e.g., rotatably supported) by proximal extensions **64***a*, **64***b* of mandrel **64**. A cam follower (e.g., a pin within a sleeve) **65** is also supported (e.g., rotatably supported) by proximal extensions **64***a*, **64***b* of mandrel **64**.

While the following description discusses the use of two handles **30***a*, **30***b*, the use of a single handle **30***a* may also be utilized without departing from the scope of the present disclosure. In order to move jaw members **110**, **120** from the open position to the closed position, handles **30***a* and/or **30***b* are squeezed, e.g., pivoted about pivot pins **34***a*, **34***b*, inwardly towards one another and housing **20**. As handle(s) **30***a*, **30***b* are pivoted in this manner, proximal ends **32***a*, **32***b* of handles **30***a*, **30***b* are approximated relative to housing **20** and one another. The approximation of proximal ends **32***a*, **32***b* of handles **30***a*, **30***b* towards one another causes extensions **140***a*, **140***b* of respective handles **30***a*, **30***b* to urge follower **75**, mandrel **64** and drive bar **62** proximally, thus approximating jaw members **110**, **120**. Movement of handles **30***a*, **30***b* toward their open position causes extensions **140***a*, **140***b* to urge cam follower **65**, mandrel **64** and drive bar **62** distally, thus causing jaw members **110**, **120** to move toward their open position, as further described below. The spring force of spring **69** may be configured such that jaw members **110**, **120** impart a closure force between jaws within a range of about 3 kg/cm^2 to about 16 kg/cm^2, although other closure forces are also contemplated.

Additionally, with reference to FIGS. **3**-**6**, extension **140***a* includes a rib **150** thereon. The shape of rib **150** is arcuate when used with a pivoting handle **30***a*; rib **150** may be linear when used with a non-pivoting handle (not shown). Rib **150** is configured to be contacted by a roller **160**.

As shown in FIGS. **4**-**6**, roller **160** is supported by a support **170**. Support **170** is fixed to housing **20** of surgical forceps **10** and includes a pin **172** extending through a leg **174** of support **170**. Pin **172** rotationally supports roller **160**. Roller **160** is longitudinally fixed with respect to housing **20** and is configured to engage rib **150** of extension **140***a*.

As handle **30***a*, and thus extension **140***a*, is moved, roller **160** moves along rib **150**. More particularly, as handle **30***a* is moved, roller **160** contacts and thus supports a distal wall **152** of rib **150**. For example, when handle **30***a* is moved generally downward (as viewed in FIG. **3**) to approximate the jaw members, for instance, roller **160** contacts distal wall **152** of rib **150**. Thus, roller **160** provides support to rib **150**, and thus handle **30***a*, during approximation of jaw members, e.g., to restrict or minimize unintended bending or flexing motion in extension **140***a*, handle **30***a*, and other features within housing **20**.

An alternate embodiment is shown in FIG. **6**A, which includes a first roller **160***a* and a second roller **160***b*. Each of first roller **160***a* and second roller **160***b* is supported by support **170**. Support **170** is fixed to housing **20** of surgical forceps **10** and includes a first pin **172***a* and a second pin **172***b* extending through leg **174** of support **170**. First pin **172***a* rotationally supports first roller **160***a*, and second pin **172***b* rotationally supports second roller **160***b*. First and second rollers **160***a*, **160***b* are longitudinally fixed with respect to housing **20** and are configured to engage rib **150** of extension **140***a*.

As handle **30***a*, and thus extension **140***a*, is moved, first and second rollers **160***a*, **160***b* move along rib **150**. More particularly, as handle **30***a* is moved, first roller **160***a* contacts and thus supports distal wall **152** of rib **150**. For example, when handle **30***a* is moved generally downward (as viewed in FIG. **3**) to approximate the jaw members, for instance, first roller **160***a* contacts distal wall **152** of rib **150**. Thus, first roller **160***a* provides support to rib **150**, and thus handle **30***a*, during approximation of jaw members, e.g., to restrict or minimize unintended bending or flexing motion in extension **140***a*, handle **30***a*, and other features within housing **20**. Additionally, when handle **30***a* is moved generally upward (as viewed in FIG. **3**) to open the jaw members, for instance, second roller **160***b* contacts a proximal wall **152***b* of rib **150**. Thus, second roller **160***b* provides support to rib **150**, and thus handle **30***a*, during opening of jaw members, e.g., to restrict or minimize unintended bending or flexing motion in extension **140***a*, handle **30***a*, and other features within housing **20**.

During use, a surgeon may desire fine (vs. gross) control of jaw members **110**, **120** during some stages of use. For example, the surgeon may wish to have greater control of the movement of the jaw members **110**, **120** during dissection of tissue, manipulation of tissue, and precise placement of jaw members **110**, **120** about target tissue. For such fine control of jaw members **110**, **120**, a relative large amount of travel of handles **30***a*, **30***b* (or a single handle) would correspond to a relative small amount of travel of jaw members **110**, **120**. Some surgeons may also desire to have a high mechanical advantage during other stages of use. For example, a surgeon may wish to utilize a high mechanical advantage while applying compression force to tissue. To achieve such a high mechanical advantage, a relative small amount of travel of handles **30***a*, **30***b* would correspond to a relative large amount of travel of jaw members **110**, **120**. Typically, surgical instruments only allow for either fine control of jaw members **110**, **120** or a high mechanical advantage. Examples of one surgical forceps configured to allow both fine control of jaw members and a high mechanical advantage at different stages of the actuation stroke of handles is described in U.S. Provisional Patent Application Ser. No. 62/247,279, filed on Oct. 28, 2015, the entire contents of which is incorporated by reference herein.

With particular reference to FIG. **7**, to help ensure that contact is maintained between follower **75** and a proximal cam surface **142***a*, and between cam follower **65** and a distal cam surface **148***a* (e.g., to account for manufacturing tolerances, and/or to allow greater manufacturing tolerances, thus reducing costs), surgical forceps **10** may include an engagement spring **180** disposed between a proximal wall **64***c* of mandrel **64** and cam follower **65**. Engagement spring **180** is configured to urge cam follower **65** proximally toward and into contact with distal cam surface **148***a*. Engagement spring **180** may be cone-like (e.g., frusto-conical) in shape, or a so-called Belleville washer.

With particular reference to FIGS. **8**-**12**, an additional embodiment of surgical forceps is shown and is indicated by reference character **2000**. Surgical forceps **2000** is similar to surgical forceps **10** discussed above and only the differences are discussed in detail herein.

Surgical forceps **2000** includes a movable handle **2030***a* and a finger loop **2030***b*. In lieu of finger loop **2030***b*, surgical forceps **2000** may include a second movable handle. Handle **2030***a* includes an extension **2032** having a groove or channel **2040** defined therein. A roller **2050** is movably positioned within channel **2040**.

More particularly, channel **2040** extends within extension **2032** of handle **2030***a* and is defined by a proximal wall **2042** and a distal wall **2044** (FIG. **11**). The shape of channel **2040** is arcuate when used with a pivoting handle **2030***a*; channel **2040** may be linear when used with a non-pivoting handle (not shown). Channel **2040** includes a width "wc" (FIG. **12**) which may be uniform along its entire length or which may vary along at least a portion of its length.

Roller **2050** is supported by a support **2060**. Support **2060** is fixed to housing **2002** of surgical forceps **2000** and includes a pin **2062** extending through a leg **2064** of support **2060**. Pin **2062** rotationally supports roller **2050**. Roller **2050** is longitudinally fixed with respect to housing **2002** and is configured to engage channel **2040** of extension **2032**. Roller **2050** includes a width in the longitudinal direction. The width of roller **2050** is smaller than width "wc" of channel **2040**, thus enabling roller **2050** to move within channel **2040**.

As handle **2030***a*, and thus extension **2032**, is moved, roller **2050** moves within channel **2040**. More particularly, as handle **2030***a* is moved, roller **2050** contacts proximal wall **2042** and distal wall **2044** of channel **2040**. For example, when handle **2030***a* is moved generally downward (as viewed in FIG. **8**) to approximate the jaw members, for instance, roller **2050** may contact distal wall **2044** of channel **2040**; when handle **2030***a* is moved generally upward (as viewed in FIG. **8**) to move the jaw members to the open position, for example, roller **2050** may contact proximal wall **2042** of channel **2040**. Thus, channel **2040** provides support to roller **2050** at all times during manipulation of the jaw members, e.g., to restrict or minimize unintended bending motion.

The difference between the width of roller **2050** and the width "wc" of channel **2040** determines the amount of travel or "play" that handle **2030***a* can undergo while being actuated; a small difference between these distances results in a lower amount of "play."

Surgical forceps **10**, **2000** may also include features to help maintain the handle(s) in the closed position, and may include features for providing feedback to the user at certain stages of approximating or opening the jaw members. Such features are described in U.S. Provisional Patent Application Ser. No. 62/247,279, filed on Oct. 28, 2015, the entire contents of which have been incorporated by reference hereinabove.

The present disclosure also includes methods of manipulating jaw members **110**, **120** using fine and gross controls, as described above. For example, disclosed methods include moving handle **30***a*, **30***b* of surgical instrument **10** from a non-actuated position a first distance to an intermediate position to cause first jaw member **110** to move a first amount, and moving handle **30***a*, **30***b* from the intermediate position a second distance to a fully actuated position to cause first jaw member **110** to move a second amount. Here, the first distance is the same as the second distance, and the first amount is less than the second amount, thus resulting in an initial fine movement of jaw member **110**, and a subsequent gross movement of jaw member **110**.

With particular reference to FIGS. **13-16**, details of a second type of trigger assembly **200** are shown. Trigger assembly **200** of this embodiment includes a trigger **210**, a gear assembly **220**, a drive spool **230**, a knife slider **240**, a roller **250**, and a flexible drive member **260**. As discussed below, actuation of trigger assembly **200** is configured to longitudinally translate a drive member (e.g., a knife drive shaft **244**). Additionally, while trigger assembly **200** is shown used in connection with a particular surgical forceps **2000**, trigger assembly **200** may also be used in connection with surgical forceps **10**, or an additional type of surgical device.

With particular reference to FIGS. **14** and **15**, trigger **210** includes an actuation portion **212** configured for direct engagement by the user (e.g., physician), a plurality of trigger teeth **214**, and is rotatable about a trigger pin **216**. Gear assembly **220** (e.g., a cluster gear) includes a first gear **222** having a plurality of teeth **223**, and a second gear **224** having a plurality of teeth **225**. First gear **222** and second gear **224** are rotationally fixed with respect to each other, and are rotatable about a gear pin **226**.

Drive spool **230** includes a spool gear **232** having a plurality of teeth **234** (see FIG. **16**), and spool portion **236**. Drive spool **230** is rotatable about a spool pin **238**. A knife ring **242** is rotationally disposed within a portion of knife slider **240**. Knife ring **242** is rotatable about the longitudinal axis "X" with respect to knife slider **240**. Roller **250** is rotatable about a roller pin **252**. Flexible drive member **260** is in contact with spool portion **236** of drive spool **230**, knife slider **240**, and roller **250**. Flexible drive member **260** can be made from any suitable material such as nylon, a para-aramid synthetic fiber (e.g., Kevlar®), high-modulus polyethylene (HMPE), etc. for example. Flexible drive member **260** can also be made from plastic, e.g., having a rectangular cross-section (such as a zip-tie). In such embodiments, the pushing of various elements may be facilitated due to the strength of plastic. Additionally, assembly of surgical forceps **2000** may be facilitated using a plastic flexible drive member **260**, for example, as fewer loops may be necessary to accomplish each desired action (e.g., proximal and distal translation of knife slider **240**.

Details regarding the various interactions between the components of trigger assembly **200** are discussed herein with continued reference to FIGS. **13-16**. Trigger teeth **214** of trigger **210** engage or mesh with teeth **223** of first gear **222** of gear assembly **220**. Accordingly, movement of actuation portion **212** in the general direction of arrow "A" in FIGS. **13** and **14** causes rotation of trigger teeth **214** about trigger pin **216** in the general direction of arrow "B" in FIGS. **13** and **14**, which causes rotation of first gear **222** about gear pin **226** in the general direction of arrow "C" in FIGS. **13** and **14**.

First gear **222** of gear assembly **220** is rotationally fixed with respect to second gear **224** of gear assembly **220**. Teeth **225** of second gear **224** of gear assembly **220** engage or mesh with teeth **234** of spool gear **232** of drive spool **230**. Accordingly, rotation of first gear **222** about gear pin **226** in the general direction of arrow "C" causes rotation of second gear **224** about gear pin **226** in the general direction of arrow "C," which causes rotation of spool gear **232** and drive spool **230** about spool pin **238** in the general direction of arrow "D" in FIGS. **13** and **14**. Spool portion **236** of drive spool **230** is rotationally fixed with respect to spool gear **232**, such that rotation of spool gear **232** causes a corresponding rotation of drive spool **230**.

Flexible drive member **260** extends at least partially around spool portion **236** of drive spool **230**, extends at least partially around roller **250**, and is engaged with (e.g., wrapped around) a portion of knife slider **240**. Flexible drive member **260** is longitudinally fixed with respect to knife slider **240**. Accordingly, rotation of spool portion **236** of drive spool **230** in the general direction of arrow "D" causes translation of flexible drive member **260** in the general direction of arrow "E" in FIGS. **13** and **14**, which causes roller **250** to rotate about roller pin **252** in the general direction of arrow "F" in FIGS. **13** and **14**. Additionally, based on the way flexible drive member **260** engages a portion of knife slider **240** (as shown in FIG. **15**), translation of flexible drive member **260** in the general direction of arrow "E" causes knife slider **240** to move in the general direction of arrow "G" (or distally) in FIGS. **13** and **14**.

Further, and with continued reference to FIG. **16**, knife slider **240** includes a cutout **241** that rotationally supports knife ring **242**, such that knife ring **242** is rotatable about the longitudinal axis "X" with respect to knife slider **240** and with respect to trigger **210**, for example. Additionally, knife ring **242** is pinned to a knife drive shaft **244** and to drive bar **62** by a ring pin **243**, such that rotation of rotating assembly **80** causes rotation of drive bar **62** and knife ring **242** about the longitudinal axis "X" with respect to knife slider **240**. Moreover, ring pin **243** extends through a longitudinal slot **63** of drive bar **62**. Thus, longitudinal translation of knife slider **240** causes a corresponding longitudinal translation of knife ring **242** and knife drive shaft **244**.

Accordingly, actuation of trigger **210** in a first direction (e.g., in the general direction of arrow "A") causes rotation of gear assembly **220**, rotation of drive spool **230**, movement of flexible drive member **260** around spool portion **236** of drive spool **230** and around roller **250**, which causes distal translation or advancement of knife slider **240**, knife ring

242 and knife drive shaft **244** to cut tissue, for example. Additionally, movement of trigger **210** in a second direction (e.g., in the general opposite direction of arrow "A") causes proximal translation or retraction of knife drive shaft **244**.

Additionally, while the illustrated embodiments depict one type of surgical instrument (i.e., surgical forceps), the present disclosure includes the use of various features described herein in connection with other types of surgical devices including at least one pivotable handle or lever. For instance, various handle assemblies for actuating handle(s) and corresponding drive assemblies are contemplated for translating drive bar **62** and are discussed in commonly-owned U.S. Pat. No. 7,857,812, the entire contents of which are incorporated by reference herein.

Additionally, further details of a surgical forceps having a similar handle assembly to the disclosed handle assembly 30 are disclosed in U.S. Pat. No. 8,430,876, the entire contents of which being incorporated by reference herein. Further details of an electrosurgical instrument are disclosed in U.S. Pat. Nos. 7,101,371 and 7,083,618, the entire contents of which being incorporated by reference herein.

The various embodiments disclosed herein may also be configured to work with robotic surgical systems and what is commonly referred to as "Telesurgery." Such systems employ various robotic elements to assist the surgeon and allow remote operation (or partial remote operation) of surgical instrumentation. Various robotic arms, gears, cams, pulleys, electric and mechanical motors, etc. may be employed for this purpose and may be designed with a robotic surgical system to assist the surgeon during the course of an operation or treatment. Such robotic systems may include remotely steerable systems, automatically flexible surgical systems, remotely flexible surgical systems, remotely articulating surgical systems, wireless surgical systems, modular or selectively configurable remotely operated surgical systems, etc.

The robotic surgical systems may be employed with one or more consoles that are next to the operating theater or located in a remote location. In this instance, one team of surgeons or nurses may prepare the patient for surgery and configure the robotic surgical system with one or more of the surgical instruments disclosed herein while another surgeon (or group of surgeons) remotely controls the instrument(s) via the robotic surgical system. As can be appreciated, a highly skilled surgeon may perform multiple operations in multiple locations without leaving his/her remote console which can be both economically advantageous and a benefit to the patient or a series of patients.

The robotic arms of the surgical system are typically coupled to a pair of master handles by a controller. The handles can be moved by the surgeon to produce a corresponding movement of the working ends of any type of surgical instrument (e.g., end effectors, graspers, knifes, scissors, etc.) which may complement the use of one or more of the embodiments described herein. The movement of the master handles may be scaled so that the working ends have a corresponding movement that is different, smaller or larger, than the movement performed by the operating hands of the surgeon. The scale factor or gearing ratio may be adjustable so that the operator can control the resolution of the working ends of the surgical instrument(s).

The master handles may include various sensors to provide feedback to the surgeon relating to various tissue parameters or conditions, e.g., tissue resistance due to manipulation, cutting or otherwise treating, pressure by the instrument onto the tissue, tissue temperature, tissue impedance, etc. As can be appreciated, such sensors provide the surgeon with enhanced tactile feedback simulating actual operating conditions. The master handles may also include a variety of different actuators for delicate tissue manipulation or treatment further enhancing the surgeon's ability to mimic actual operating conditions.

With particular reference to FIG. **17**, a medical work station is shown generally as work station **1000** and generally may include a plurality of robot arms **1002**, **1003**; a control device **1004**; and an operating console **1005** coupled with control device **1004**. Operating console **1005** may include a display device **1006**, which may be set up in particular to display three-dimensional images; and manual input devices **1007**, **1008**, by means of which a person (not shown), for example a surgeon, may be able to telemanipulate robot arms **1002**, **1003** in a first operating mode.

Each of the robot arms **1002**, **1003** may include a plurality of members, which are connected through joints, and an attaching device **1009**, **1011**, to which may be attached, for example, a surgical tool "ST" supporting an end effector **1100**, in accordance with any one of several embodiments disclosed herein, as will be described in greater detail below.

Robot arms **1002**, **1003** may be driven by electric drives (not shown) that are connected to control device **1004**. Control device **1004** (e.g., a computer) may be set up to activate the drives, in particular by means of a computer program, in such a way that robot arms **1002**, **1003**, their attaching devices **1009**, **1011** and thus surgical instrument **10** (including end effector **300**) execute a desired movement according to a movement defined by means of manual input devices **1007**, **1008**. Control device **1004** may also be set up in such a way that it regulates the movement of robot arms **1002**, **1003** and/or of the drives.

Medical work station **1000** may be configured for use on a patient **1013** lying on a patient table **1012** to be treated in a minimally invasive manner by means of end effector **1100**. Medical work station **1000** may also include more than two robot arms **1002**, **1003**, the additional robot arms likewise being connected to control device **1004** and being telemanipulatable by means of operating console **1005**. A medical instrument or surgical tool (including an end effector **1100**) may also be attached to the additional robot arm. Medical work station **1000** may include a database **1014**, in particular coupled to with control device **1004**, in which are stored, for example, pre-operative data from patient/living being **1013** and/or anatomical atlases.

From the foregoing and with reference to the various figure drawings, those skilled in the art will appreciate that certain modifications can also be made to the present disclosure without departing from the scope of the same. While several embodiments of the disclosure have been shown in the drawings, it is not intended that the disclosure be limited thereto, as it is intended that the disclosure be as broad in scope as the art will allow and that the specification be read likewise. Therefore, the above description should not be construed as limiting, but merely as exemplifications of particular embodiments. Those skilled in the art will envision other modifications within the scope and spirit of the claims appended hereto.

What is claimed is:

1. A surgical instrument, comprising:

a housing;

an elongated shaft extending distally from the housing and defining a longitudinal axis;

an end effector assembly disposed adjacent a distal end of the elongated shaft, the end effector assembly including a first jaw member and a second jaw member, at least one of the jaw members movable with respect to the other jaw member from a spaced-apart position to a position closer to the other jaw member for grasping tissue; and

a trigger assembly disposed in mechanical cooperation with the housing and configured to longitudinally translate a drive member, the trigger assembly including a trigger, a gear assembly, a spool, a slider, and a flexible drive member, the trigger disposed in mechanical cooperation with the gear assembly, the flexible drive member configured to engage the gear assembly, the spool, and the slider, the flexible drive member configured as a continuous loop, wherein movement of the trigger with respect to the housing results in movement of the flexible drive member with respect to the housing and longitudinal movement of the slider with respect to the housing.

2. The surgical instrument according to claim **1**, further comprising a drive assembly disposed at least partially within the housing, the drive assembly including a drive bar extending at least partially through the elongated shaft such that longitudinal translation of the drive bar causes the jaw members to move between the spaced-apart position and the closer position for grasping tissue.

3. The surgical instrument according to claim **2**, wherein the drive bar is rotatable about the longitudinal axis with respect to the housing.

4. The surgical instrument according to claim **2**, wherein the drive bar is rotatable about the longitudinal axis with respect to the slider.

5. The surgical instrument according to claim **2**, wherein the trigger assembly further comprises a ring rotationally supported by the slider.

6. The surgical instrument according to claim **5**, wherein the ring is rotationally fixed with respect to the drive bar.

7. The surgical instrument according to claim **6**, wherein the ring is longitudinally translatable with respect to the drive bar.

8. The surgical instrument according to claim **5**, wherein the ring is rotatable relative to the housing.

9. The surgical instrument according to claim **5**, wherein the slider is rotationally fixed relative to the housing.

10. The surgical instrument according to claim **2**, wherein the drive member is longitudinally translatable with respect to the drive bar.

11. The surgical instrument according to claim **10**, wherein the drive bar is rotatable with respect to the drive member.

12. The surgical instrument according to claim **1**, wherein the gear assembly includes a first gear and a second gear, the first gear configured to engage the trigger, and the second gear configured to engage the spool.

13. A trigger assembly for use with a surgical instrument, the trigger assembly comprising:

a trigger;

a gear assembly disposed in mechanical cooperation with the trigger;

a spool;

a slider; and

a flexible drive member, the flexible drive member configured to engage the gear assembly, the spool, and the slider, wherein actuation of the trigger results in movement of the flexible drive member with respect to the spool and longitudinal movement of the slider with respect to the spool, wherein an amount of contact between the flexible drive member and the spool remains constant during actuation of the trigger.

14. The trigger assembly according to claim **13**, further comprising a ring rotationally supported by the slider.

15. The trigger assembly according to claim **14**, wherein the ring is longitudinally translatable with respect to the spool.

16. The trigger assembly according to claim **13**, wherein the gear assembly includes a first gear and a second gear, the first gear configured to engage the trigger, and the second gear configured to engage the spool.

17. The trigger assembly according to claim **16**, wherein the first gear and the second gear are rotationally fixed with respect to each other.

18. The trigger assembly according to claim **13**, wherein the flexible drive member is in contact with the spool and the slider.

19. The trigger assembly according to claim **13**, wherein the spool includes a spool gear having a plurality of teeth configured to engage a portion of the gear assembly.

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